Improving hydropower constraints modeling for a national power grid

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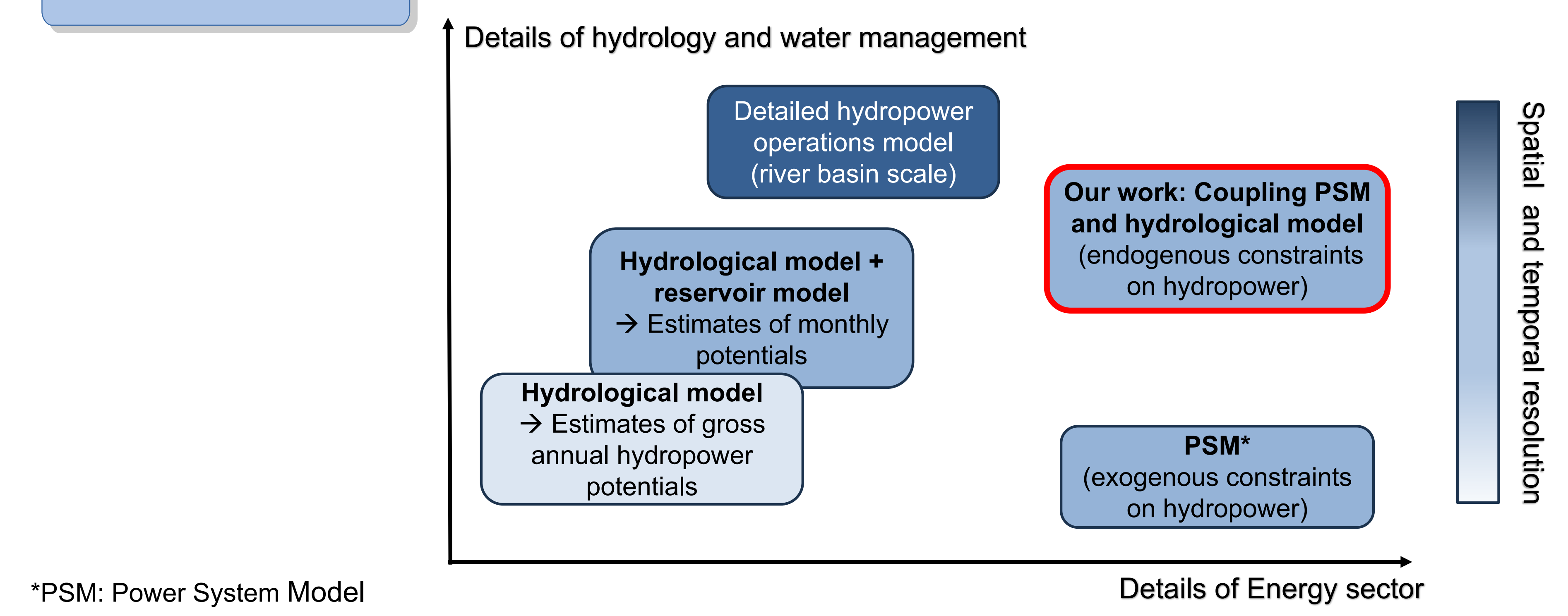
Introduction

As climate policies encourage the integration of variable renewable energy into the grid, hydropower can be an important asset for enhancing grid flexibility. However, it will be subject to evolving constraints related to water resources and the operation of muti-purpose reservoirs.

How to account for these constraints in power system modeling?

We explore the value of coupling a power system model with a hydrological model that represents the operation of hydroelectric dams.

Literature review



Details of hydrology and water management

Detailed hydropower operations model (river basin scale)

Our work: Coupling PSM and hydrological model (endogenous constraints on hydropower)

Hydrological model + reservoir model → Estimates of monthly potentials

Hydrological model → Estimates of gross annual hydropower potentials

PSM* (exogenous constraints on hydropower)

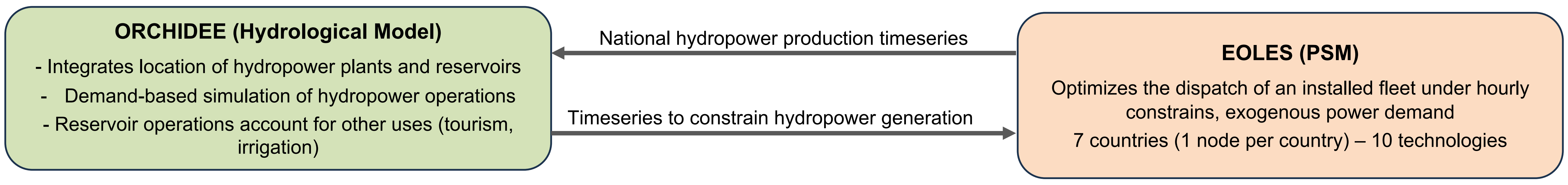
Spatial and temporal resolution

Details of Energy sector

*PSM: Power System Model

Methods

Iterative simulations of ORCHIDEE and EOLES



ORCHIDEE (Hydrological Model)

- Integrates location of hydropower plants and reservoirs
- Demand-based simulation of hydropower operations
- Reservoir operations account for other uses (tourism, irrigation)

National hydropower production timeseries

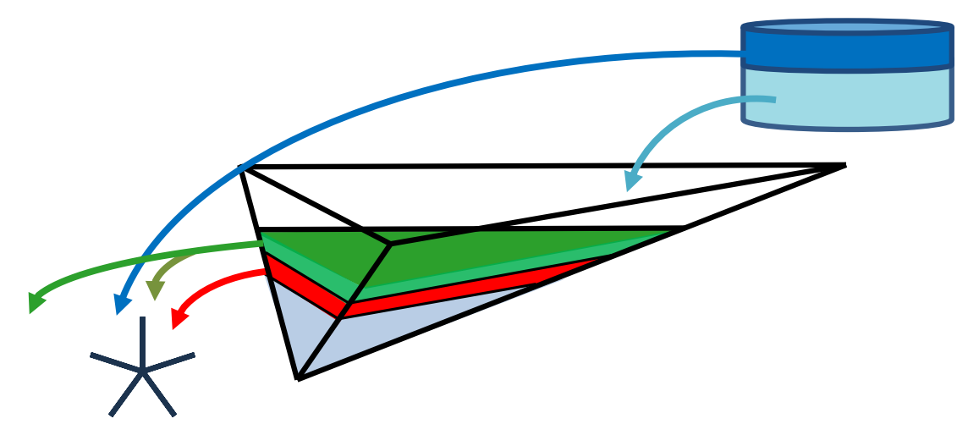
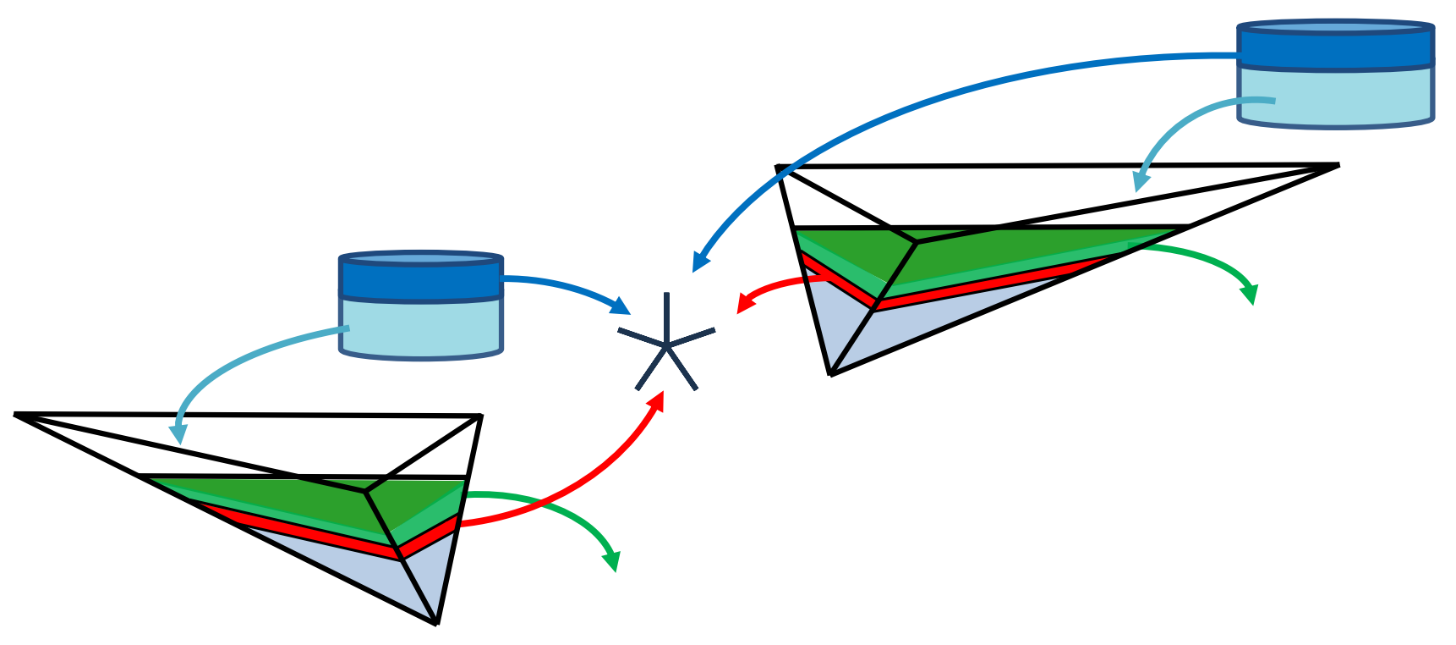
Timeseries to constrain hydropower generation

EOLES (PSM)

Optimizes the dispatch of an installed fleet under hourly constrains, exogenous power demand

7 countries (1 node per country) – 10 technologies

Hydropower constraints in EOLES

	Old method	New method: Coupling with hydrological model
Run-of-river	Capacity factor from observations	Capacity factor based on ORCHIDEE's simulated river discharges
Reservoir	Monthly production from observations, free optimization inside a month $$\sum_{h \in month} \boldsymbol{G_h} = Prod_{month}$$	New constraints based on ORCHIDEE's simulations EOLES' inputs: - $Inflows_h$ = Water entering the reservoir - $Spill\_pot_h$ = Energy potential of the spillage - $Rmin_h$ = Constrained releases from the reservoir (irrigation, ecological spill) - $Rmin\_pot_h$ = Energy potential of constrained releases - $Pmax_h$ = Maximal available capacity (tourism)  $\boldsymbol{S_{h+1}} = \boldsymbol{S_h} + Inflows_h - Rmin_h - \boldsymbol{Relec_h}$ $\boldsymbol{G_h} \leq Spill\_pot_h + Rmin\_pot_h + \boldsymbol{Relec_h}$ $\boldsymbol{G_h} \leq Pmax_h$ → a new **model variable in EOLES:** $\boldsymbol{Relec_h}$= Reservoir release intended for hydropower
Poundage	Included in run-of-river capacity factor	Modeled as reservoir plants
PHS*	Modeled as a battery $\boldsymbol{S_{h+1}} = \boldsymbol{S_h} + \eta_{phs} * \boldsymbol{\overline{G}_h} - \boldsymbol{G_h}$	Constraints on upstream and downstream reservoirs based on ORCHIDEE's simulations  $\boldsymbol{S_{h+1}} = \boldsymbol{S_h} + \eta_{phs} * \boldsymbol{\overline{G}_h} + Inflows_h - Rmin_h - \boldsymbol{Relec_h}$ $\boldsymbol{G_h} \leq Spill\_pot_h + \boldsymbol{Relec_h}$ $\boldsymbol{G_h} \leq Pmax_h$ $\boldsymbol{\overline{S}_{h+1}} = \boldsymbol{\overline{S}_h} + \boldsymbol{G_h} + Inflows\_p_h - Rmin\_p_h - \boldsymbol{Rpump_h}$ $\boldsymbol{\overline{G}_h} \leq Spill\_pot\_p_h + \boldsymbol{Rpump_h}$ $\boldsymbol{\overline{G}_h} \leq \overline{Pmax_h}$

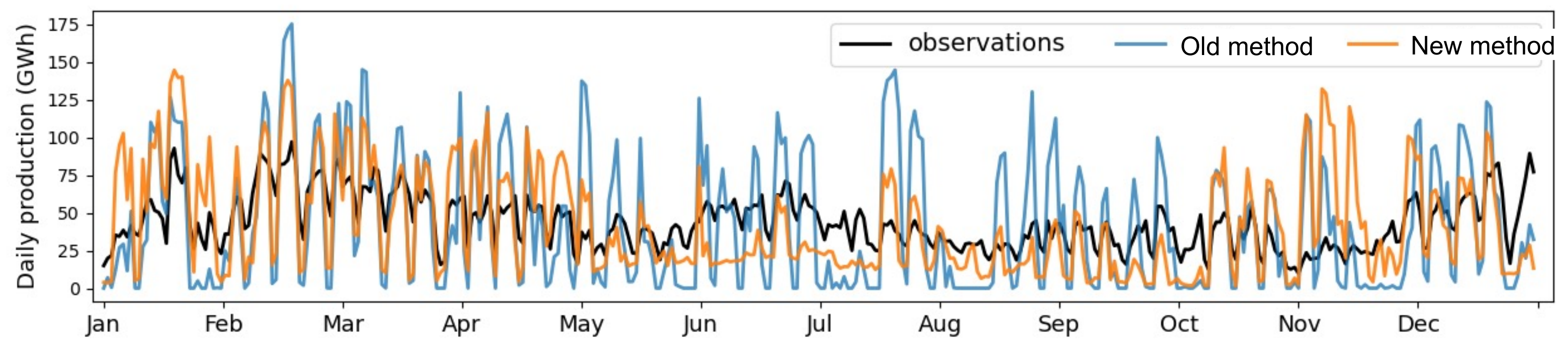
*PHS: Pumped-Hydro Storage

Results: Comparison of hydropower generation simulated by EOLES in 2016 for both methods

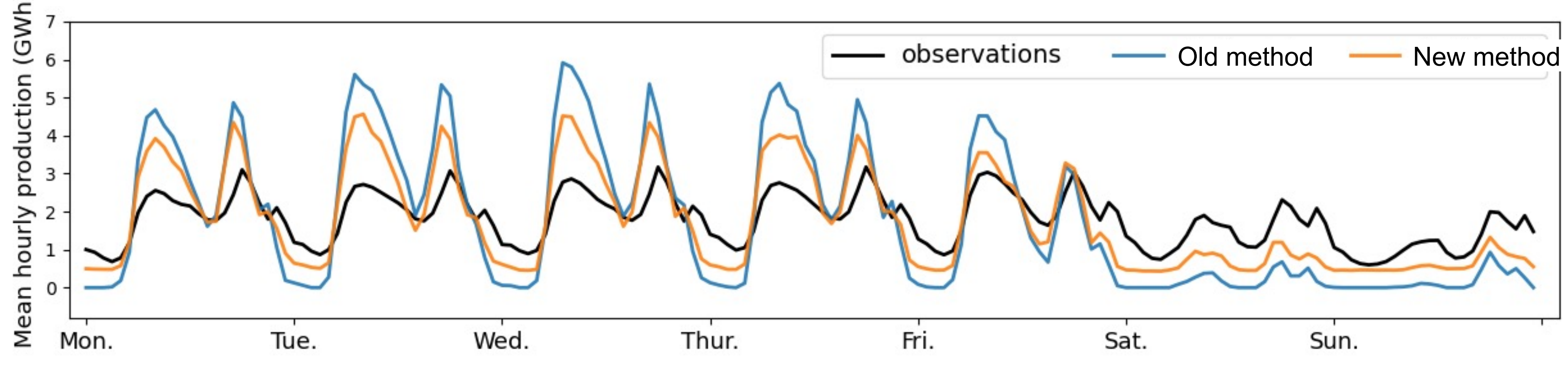
- **Better representation of constraints on reservoir plants generation**

French power system cost: 6.026 b€ vs 6.084 b€

Daily production reservoirs (GWh)

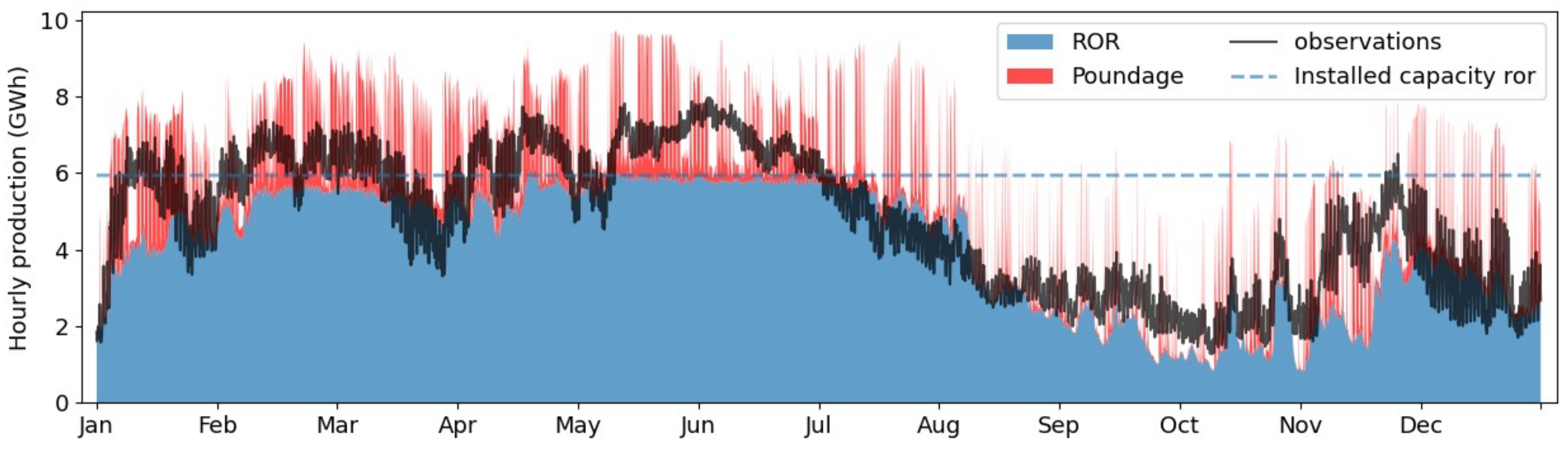


Mean hourly production reservoirs (GWh)



- **Account for the flexibility of poundage plants**

French power system cost: 6.084 b€ (fixed capacity factor) vs 5.997 b€ (flexibility)



RMSE - Simulations compared to observations

	Old method	New method
Reservoir production	232 GWh	185 GWh (-17%)
PHS production	144 GWh	116 GWh (-13%)
PHS pumping	131 GWh	110 GWh (-16%)

Conclusion and perspectives

- We propose a new method to constrain hydropower production in power system models based on outputs from a hydrological model.
- This new method significatively improves simulated hydropower generation schedule as it ensures consistency with water management simulated in the hydrological model.

➢ A promising method to explore the impacts of water resource constraints on power system performance

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